A Restudy of the Reported Occurrence of Schist on Truk, Eastern Caroline Islands[1]

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INTRODUCTION

THE ISLANDS of the western Pacific Ocean are commonly grouped into two main divisions: continental and oceanic. The former are believed to be the remnants of a continental area; the latter are thought always to have been islands. The distinction is based upon several facts, among which are the types of rocks of which the islands are composed, the major structure lines of the ocean basins, and the structures of the islands themselves. The location of the eastern border of the former Melanesian or Australasian continent has been the subject of considerable speculation. A number of authors have presented "lines" showing the distribution of different rock types, structural data, and other geologic information in the western Pacific islands, and from these have made various deductions about the former extent of the Melanesian continent. Among these are the "border of the South Pacific Basin" (Marshall, 1912), the "andesite line" (Born, 1933), the "metamorphic–plutonic" and "probable boundary of the former Melanesian continent" lines (Ladd, 1934), and the "Sial line" (Stearns, 1945; 1946). Inasmuch as many of the islands in the vicinity of these "lines" were closed to all except Japanese geologists from about 1916 until quite recently, most of the evidence for their position and the subsequent classification of the islands on either side of them as continental or oceanic has been derived largely from a study of the older literature. It is the purpose of the present paper to revise a portion of the "metamorphic–plutonic" and "continental boundary" lines of Ladd in accordance with some recent observations made on Truk, one of the key island groups determining the position of these lines.

Acknowledgments: The writer is deeply indebted to Miss Jewell J. Glass and C. S. Ross for the petrographic examinations and descriptions of the various rocks and for the photomicrograph (Fig. 2). Thanks are also due to G. A. Macdonald, H. S. Ladd, and J. I. Tracey, all of whom have read and criticized the manuscript and have offered many helpful suggestions.

PREVIOUS WORK

Ladd (1934: 51, Fig. 6) gave a brief description of the former Melanesian continent and outlined on a map of the Pacific Ocean south of lat. 10° N. the probable eastern boundaries of several types of rocks, as well as the probable eastern boundary of the former Melanesian continent. His map, with some modifications, is reproduced as Figure 3 in this paper.

In the original figure, one of the lines, designated the "metamorphic–plutonic line," starts just east of Yap, extends southeastward around the Truk group, then turns abruptly south to New Ireland and thence southeastward along the northeastern edge of the Solomon Islands. A second line, hereafter referred to as the "continental line," marks the "probable former boundary of the Melanesian continent and true structural boundary of the Pacific Basin" and lies just east of and roughly parallels the "metamorphic–plutonic line." Both lines were drawn so as to include Truk among the continental islands and to exclude Ponape and Kusaie, high volcanic islands lying east of Truk and geologically similar to it.

The inclusion of Truk among the continental islands was based on the reported occurrence of schist on one of the islands of the group (Daly, 1916). Daly's paper, in turn, was not based on direct observation but on information

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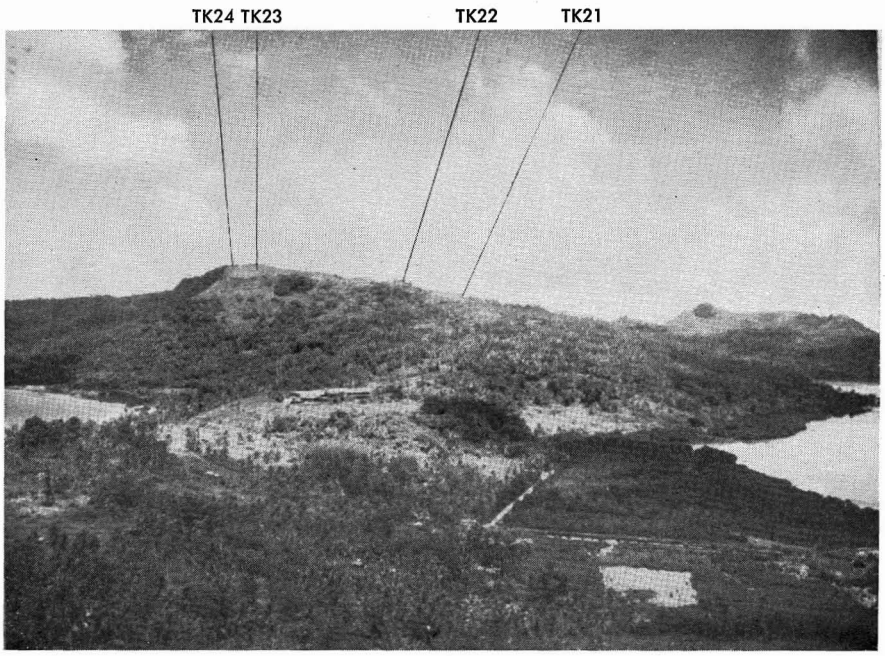


FIG. 1. Looking west from the lighthouse on the eastern end of Moen Island showing localities on Mt. Witipon from which trachytic material was collected. The approximate extent of this material is shown by the light color and the absence of trees. Mt. Tonaachau at right. PHOTO BY JOSIAH BRIDGE.

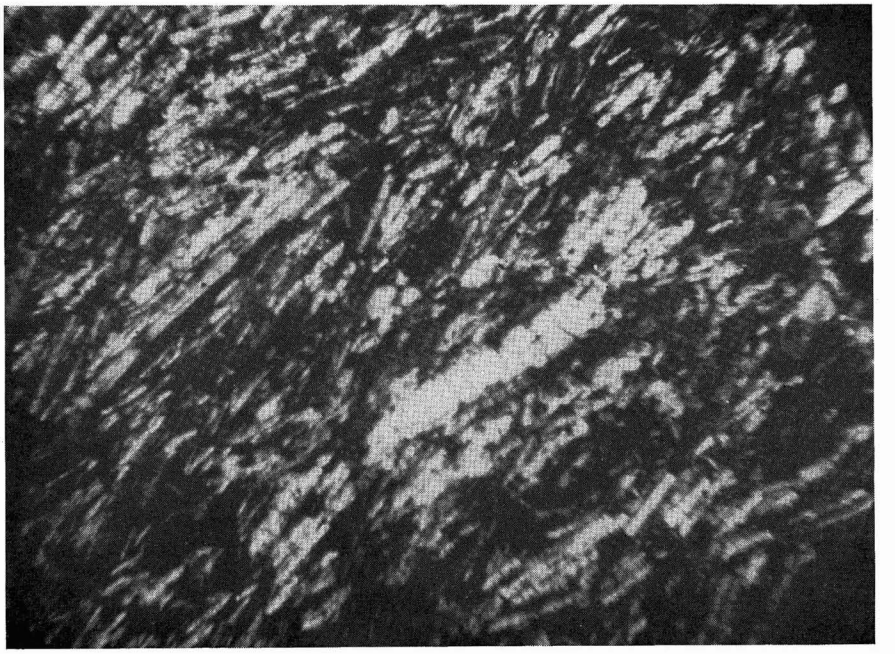
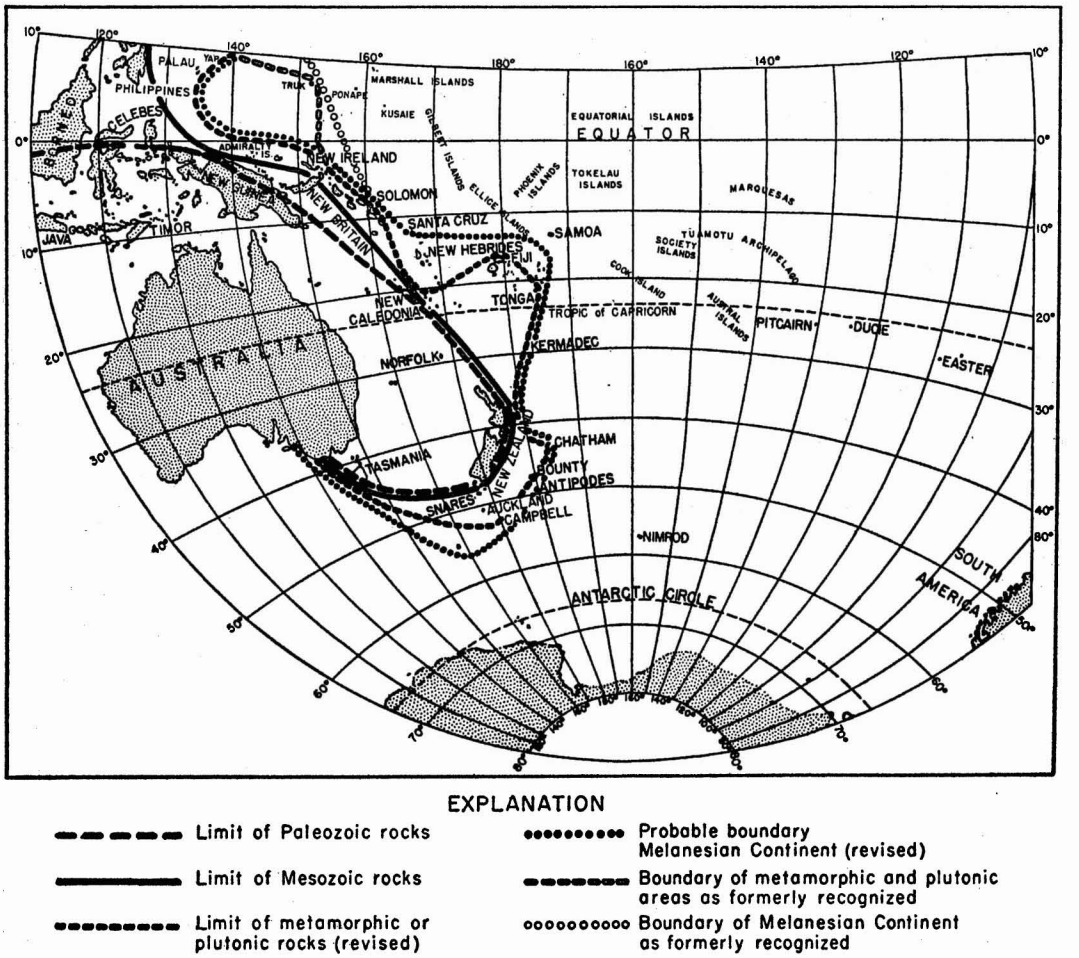


FIG. 2. Photomicrograph of trachytic material from specimen TK-24. Crossed nicols; × 86. PHOTOMICROGRAPH BY C. S. ROSS.

contained in papers by various authors. In Tables I and II, Daly credited the reporting of amphibolite schist on Truk to Kramer (1908). Kramer's statement is short and explicit and may be translated as follows:

The Truk atoll is a combination of high islands surrounded by an atoll ring. Everywhere, insofar as I have examined the high islands, I found only volcanic rocks, of which feldspar basalt was by far the most abundant type. The only exception to this is Mt. Vidiboen, a bare mountain 275 m. high on the northeastern part of the large island of Vela. The eastern slope of this mountain rises so gradually that one can easily climb it on horseback, in fact a wagon road could be built to the summit without great difficulty. This mountain is unforested, and its rock is amphibolite schist similar to the rock on Yap. Dr. Klautzsch confirms my identification.

Stearns (1945, 1946) has drawn the "Sial line" so as to include the Caroline submarine plateau and all of the high, volcanic islands rising above it, on the Sialic or continental side. He states (1945: 615) that "The Sial line lies a little to the east of the andesite line of Gutenberg" and adds that "the line is the probable boundary of the continental platform of Australasia" and that "these islands [west of the Sial line] might be called Sialic islands from the character of their basement, as all are com-



EXPLANATION

- Limit of Paleozoic rocks
- Limit of Mesozoic rocks
- Limit of metamorphic or plutonic rocks (revised)
- Probable boundary Melanesian Continent (revised)
- Boundary of metamorphic and plutonic areas as formerly recognized
- Boundary of Melanesian Continent as formerly recognized

FIG. 3. Map of the Pacific Ocean south of lat. 10° N., showing the general distribution of various types of rock, the probable eastern boundary of the former Melanesian continent, and the true structural boundary of the Pacific Basin. (After Ladd, 1934.)

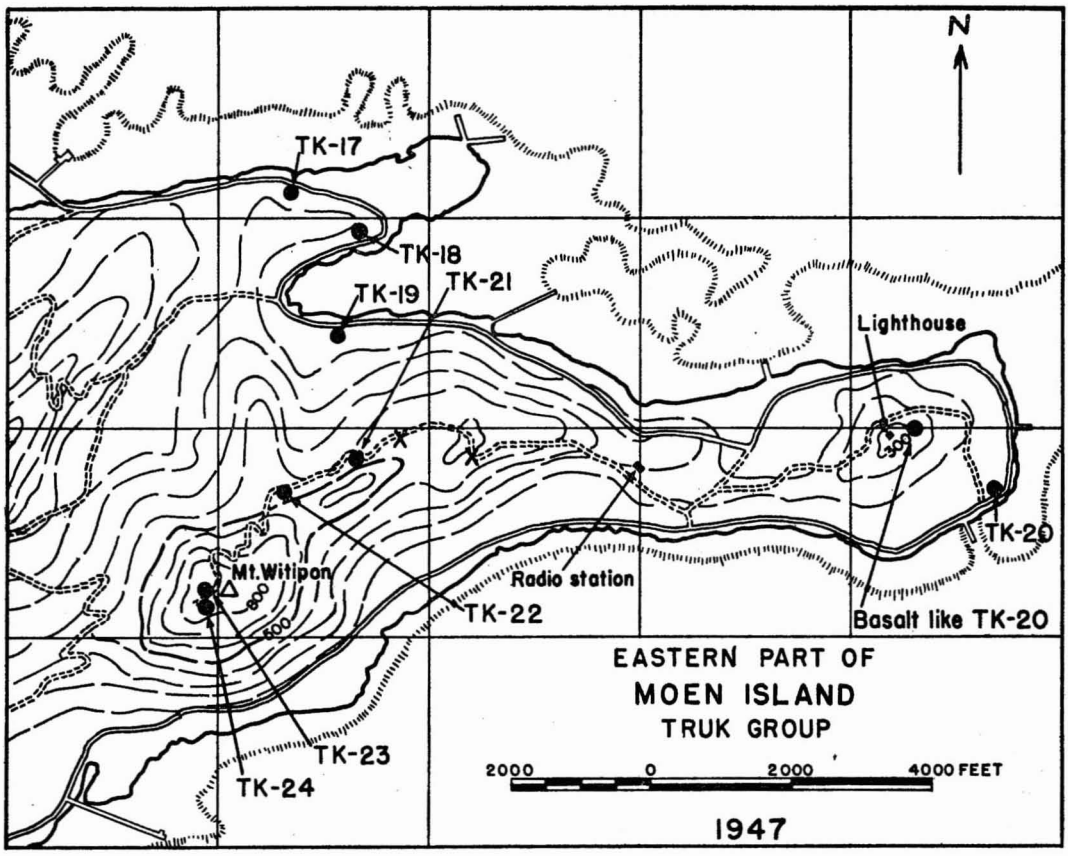


FIG. 4. Sketch map of the eastern part of Moen Island, showing Mt. Witipon and the localities from which rock samples were collected.

posed of, or believed to be underlain by, continental rocks." He offers no evidence in support of these statements, and for the reasons to be given, the writer prefers the arrangement shown in Figure 3.

FIELD WORK

In August, 1946, the writer spent 10 days in Truk studying the geology and mineral resources of the islands in connection with the Economic Survey of the former Japanese Mandated Islands. This survey was conducted by the U. S. Commercial Company, a subsidiary of the Reconstruction Finance Corporation, and was made at the request of the U. S. Navy.[3] At the time of the visit the writer was not familiar with Kramer's report and consequently made no special search for metamorphic rocks. Later, during the preparation of the report, his attention was called to Kramer's statement, and he was at once impressed with the similarity of the description of the topography and vegetation of Mt. Vidiboen on Vela Island with conditions observed on the eastern part of Moen Island.

Subsequent inquiry has established the fact that the two islands are identical. According to Karl J. Pelzer (oral communication, 1947), a geographer with the Economic Survey who was stationed on Truk for 4 months in the spring and summer of 1946, Vela is one of the many names which have been applied to Moen (Wona) Island, and Vidiboen is clearly a variant of Witipon, an 890-foot peak which dominates the eastern end of this island (Figs.

[3] The geologic reports resulting from this survey have been placed in open file in the offices of the U. S. Geological Survey, Washington, D. C., and Honolulu, T. H. A microfilm of the entire report has been deposited in the Library of Congress.

1 and 4). The general form of the mountain agrees quite well with Kramer's description, the upper slopes are only sparsely forested, and there is a wagon road along the eastern spur which reaches the summit. This is the only one of the three high peaks on Moen which is reached by a road. The slopes of the upper half of Witipon are covered with a dense growth of coarse grass, ferns, low brush, and scattered trees, and stand in sharp contrast to the densely forested slopes of the other peaks on the island (Fig. 1). Thus there appears to be little doubt of the correct identification of the region described by Kramer.

In the course of the investigations, Witipon was climbed on two different occasions, rock samples were collected at several localities (Fig. 4), and it is believed that a representative suite was obtained. The lower part of the mountain is composed of a series of basalt flows. Two distinct types, one porphyritic, the other non-porphyritic, may be recognized in hand samples. These basalts are capped by what appears to be a thick bed of well-stratified tuff, but which has actually been determined as a trachytic flow. This flow is at least 300 feet thick. The entire series dips north at low angles, commonly less than 5 degrees.

It is believed that this trachytic flow, represented in the collections by specimens TK-21, 22, and 24,[4] is the rock which Kramer identified as schist. The fine, parallel, flow structure, and the glistening, micaceous-appearing, freshly broken surfaces, particularly those which are parallel to the flow lines, give this rock a schistose appearance, so that superficially it resembles the chlorite and amphibolite schists found on Yap. However, it is much lighter in color, and its mineralogic composition and texture as seen in thin sections (Fig. 2) are totally different. According to G. A. Macdonald (personal communication, 1948), the Hawaiian trachytes and oligoclase andesites commonly have well-developed, thin, tabular feldspar plates oriented parallel to the flow planes. The surfaces of these plates often exhibit a micaceous-appearing sheen, caused by the parallel orientation of innumerable tiny feldspar grains, causing the rock to resemble a fine-grained mica schist. This explanation applies equally well to the Truk specimens.

No other occurrence of this trachytic material was found, either on Moen or on the other islands which were visited in the Truk group. However, this does not rule out the possibility of other occurrences, for the examination was at best a hasty reconnaissance and many of the large islands were not visited.

Mt. Chukumong (Teroken, on H. O. Chart 6047), 1,214 feet, the highest peak on Moen Island, lies about 1.25 miles west of Witipon. If the regional strike and dip of the trachytic material continue westward without appreciable change, this material should cap the summit of Mt. Chukumong, and should also appear in the slopes of Mt. Tonaachau (794 feet), the conspicuous peak on the northwestern tip of Moen Island (Fig. 1). No definite information about the kind of rock on its summit is available. However, the upper slopes are covered with a dense forest, totally unlike the grassy upper slopes of Witipon, and this suggests that the summit may be underlain by a different type of rock. Mt. Tonaachau was climbed from two different sides and only basalts and basaltic agglomerates were seen. Macdonald (personal communication, 1948) says that trachytic flows which he has observed on other oceanic islands are commonly extremely localized, and that no special structural assumptions are necessary to account for the local distribution of this material.

The western and northwestern shores of the island were examined and no indications of metamorphic rock were found. It is possible, but in the writer's opinion highly improbable, that such rocks occur along the southern and southeastern coasts, which were not studied.

[4] The specimens described in this article, together with rocks collected from other islands visited on this trip, are now in the laboratories of the U. S. Geological Survey, Washington, D. C. They will eventually be deposited in the U. S. National Museum. A duplicate set is already on deposit in the Bernice P. Bishop Museum in Honolulu.

PETROGRAPHY

The specimens collected on Moen Island have been examined by Miss Jewell J. Glass of the U. S. Geological Survey, and the following quotations are taken from her report:

TK-19, TK-20, black, porphyritic volcanic rock. Identified as: *Porphyritic basalt.* This rock is fresh and represents a typical example of porphyritic olivine basalt. The phenocrysts consist of unaltered crystals of olivine, augite, and bytownite. The groundmass consists of a net-work of feldspar (plagioclase) laths, fine-grained augite and olivine, with abundant octahedra of magnetite.

TK-17, TK-18, dense, black volcanic rock. Identified as: *Fine-grained basalt.* Different in texture but the same in composition as TK-19 and TK-20 (described above). The groundmass consists of closely packed laths of plagioclase, fine grains of olivine, swarms of black granules of magnetite and a few phenocrysts of augite. In TK-18 the olivine plates have altered to iddingsite.

TK-24, pale gray, fine-grained rock containing a scattering of feldspar phenocrysts. Identified as: *Trachytic rock.* This is an extrusive igneous rock. In thin section it shows, in the crystallized groundmass, typical trachytic structure. The groundmass consists essentially of minute lath-shaped feldspar crystals having a distinct parallel arrangement, or flow pattern, and a sprinkling of tiny granules of magnetite. The tabular feldspar phenocrysts show a zonal banding and indications of multiple twinning. The irregular optical properties of the feldspar indicate that it has undergone some internal structural change. Minute flakes of biotite and chlorite are scattered throughout the mass, and a few remnants of resorbed biotite crystals remain. A small percentage of a brownish material occupies spaces between the feldspar laths. Some of it resembles glass, but most of it is birefracting and appears to be fine-grained aggregates of ferromagnesian minerals. Occasionally a minute grain of augite is observed.

TK-21. This specimen is the same type of rock as TK-24. However it has been considerably altered by weathering. A crushed sample of the more altered portion of the rock contains a platy or apparently micaceous mineral, roughly hexagonal in outline, and which is an alteration product of undetermined composition.

TK-22, cream-colored, soft, chalk-like material. Identified as: Completely altered product of the trachytic rocks described above. Thermal analysis was not conclusive, neither was the x-ray pattern. Suffice it to call the material clay until more work can be done.

TK-23 consists of reddish-tan, irregularly shaped, nodular material, associated with clays (TK-23-a). These overlie the trachytic material and are believed to have been derived from it. The nodules have been determined to be bauxite.[5]

CONCLUSIONS

The placing of the continental line involves two general classes of factors: (1) differences in the kind and composition of the rocks forming the islands and (2) differences in structures. The latter is possibly the more important and may be further subdivided into: (a) broad major structures reflected by the larger features of the ocean bottom and (b) lesser structural features which may be observed in the rocks exposed on the various islands in question. The importance of any set of criteria varies greatly from place to place, and all of the above factors have been used in the present relocation of the lines.

In view of the identification of Kramer's material as a trachytic flow and of the observations made on Moen and on many of the adjacent islands, the occurrence of metamorphic rocks on Truk now seems highly improbable. The rocks collected on Truk are quite similar to those found on Ponape and Kusaie, and quite different from those observed on the high islands to the west and southwest, a fact already noted by Yossii (1937: 74, Tables I, II), who lists trachyte from Ponape, but not from Truk or Kusaie. This suggests that these three island groups (Truk, Ponape, and Kusaie) are the deeply eroded summits of a group of volcanoes rising above the submarine Caroline plateau, and that they are more nearly analogous to the Hawaiian volcanoes than to the various island groups lying to the west and southwest. There is, therefore, no petrologic reason for including

[5] See "On the Occurrence of Bauxite on Truk" on page 223 of this issue.

the islands of this group with the continental islands.

Structural evidence also favors the exclusion of the Caroline submarine plateau from the continental area. Ladd's original lines (Fig. 3), drawn to outline occurrences of metamorphic and plutonic rocks, cross this plateau between Truk and Ponape, thereby placing Truk and the western half of the plateau in the continental area and leaving Ponape, Kusaie, and the eastern half in the oceanic area, while Stearns (1945, 1946) places the entire Caroline group in the continental area. A study of existing bathymetric charts (Int. Hydrographic Bureau, 1940) shows little in the configuration of the ocean bottom to favor such a division. The Caroline plateau is shown as a number of irregular elevations rising above the 5,000-meter contour and not separated from the basins on either side by deep trenches or other indications of major structural features. However, it must be recognized that most of the bathymetric charts now available have been constructed from insufficient data and that the topographic features shown on them are at best only approximations. The most reliable chart of recent date (H.O. chart 5485) does not extend far enough east to include the eastern Carolines. A comparison of this chart with earlier ones shows many important refinements in ocean-bottom topography which have been made possible by the inclusion of new data.

The "metamorphic–plutonic" and "continental boundary" lines, as here drawn (Fig. 3), for the most part follow major structural features. These are the West Caroline and Palau trenches, profound deeps with maximum depths of 4,500 and 3,500 fathoms, which lie just east of and parallel to the Yap and Palau ridges (H.O. chart 5485). Southwest of the Palau Islands the lines swing abruptly southeast along the northeast base of the submarine ridge on which the Solomon and Admiralty Islands are located and eventually join the continental lines as drawn by Marshall (1912) and Ladd (1934). No well-marked structural trench is present along the base of this ridge, the average depths being 2,000 to 2,500 fathoms, with only a few points exceeding the higher figure. However, there is a marked break in slope at the base of this ridge, which is in direct prolongation with the trend of the great Mindanao trench, and this suggests that it might be the diminishing extension of a major structural line. The northeastern slope of the Admiralty–Solomon-Island ridge is similar to the northern front of the Caroline plateau, having about the same degree of slope although the latter descends to somewhat greater depths. On the basis of the known configuration of the ocean bottom as shown on the existing bathymetric charts there is little choice between the continental line as here drawn and the "Sial line" of Stearns (1945, 1946). The distinction must be made on other evidence.

Final reasons for placing the "metamorphic–plutonic" and "continental lines" so as to exclude the Caroline submarine plateau from the continental area are the absence of extensive deformation and evidence of recent uplift in the rocks of the high islands which rise above it, a striking contrast to conditions on the high islands lying to the west of the "continental line."

On Truk, Ponape, and Kusaie there are no metamorphic rocks, and there is little or no evidence of extensive folding or faulting. Such dips as may be seen in the various lava flows are gentle, and may well be original. There are no strongly elevated and tilted limestone terraces, such as are common in the Mariana Islands and to a lesser extent in the islands of the Palau and Admiralty groups. In fact, the occurrence of limestone on Truk, Ponape, and Kusaie is limited to the low, discontinuous, 5- to 7-foot bench which partially surrounds most of the high islands. On Truk, Ponape, and Kusaie there are indications of topographic benches at relatively high elevations. These have been interpreted by Tayama (1939) as terraces of marine origin, older than the surface upon which the Plio-Pleistocene limestones of the Mariana, Palau, and Admiralty groups were deposited. The absence of metamorphism

and deformation in the volcanic series and the absence of highly elevated and tilted limestones of Plio-Pleistocene age suggest that the plateau has been a relatively stable unit since the middle part of the Tertiary period.

In the southern Mariana Islands the Tertiary and early Quaternary limestones have been raised as much as 1,500 feet above the present sea level (Rota). Locally the strata have been highly tilted and the surfaces of marine terraces have been offset and tilted by faulting (Guam, Rota, Tinian, Saipan). Moreover, the volcanic rocks underlying these limestones have been strongly folded as well as faulted (Guam, Saipan). All evidence at hand indicates that diastrophic forces were active in the Mariana Islands throughout the Tertiary, and that they are still going on. In the Palau Islands the uplift of the Plio-Pleistocene limestones amounts to at least 700 feet (Urukthapel Island), and in the Admiralty group, limestones, presumably of the same age, have been raised at least 200 feet (Manus). The volcanic rocks upon which these limestones rest have been moderately folded and faulted, but there is no evidence of regional metamorphism in the rocks seen in either of these groups.

The Yap ridge appears to be older, and, at the present time, more stable than either the Mariana or Palau ridges. No raised limestones have been found on Yap, and in this respect the group resembles the high islands of the eastern Carolines. The position of Yap with respect to major structural features, together with the fact that most of the rocks exposed on its islands are well metamorphosed and are of typical continental varieties, is responsible for placing it west of the continental line.

Note: After this paper was transmitted my attention was called to two other papers, one botanic (Selling, 1947), one geologic (Bryan, 1945), which contain maps showing the position of one or more lines in the western Pacific Ocean. A third and highly important paper (Hess, 1948) appeared while this article was in press. Although no mention of these papers is made in the text they are included in the list of references.

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